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19 min read

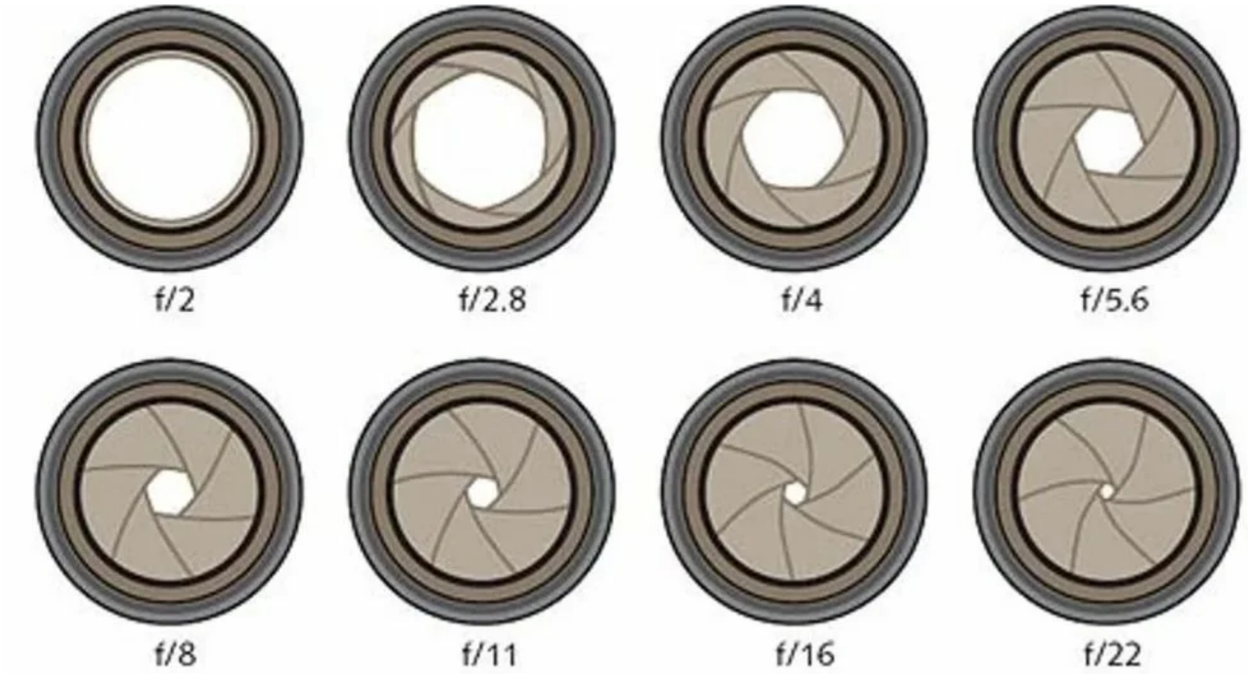
83. Why did NASA order an ultra-fast lens for a million dollars and why did they not shoot anything?

If you were interested in the topic of flights to the moon, you probably read about the following fact: NASA ordered super-high-aperture optics in Germany, from the Zeiss company (Carl Zeiss Jena). It was reported that they are needed to photograph the far side of the moon. A total of 10 Karl Zeis Planar f / 0.7 lenses with a focal length of 50 mm were manufactured: one remained with the company, six were bought for NASA. The other 3 went to Stanley Kubrick. These were insanely expensive lenses, one of a kind, costing about a million dollars each. They were made in 1967, i.e. 2 years before the planned flight to the moon. And these lenses have no analogues so far.

Karl Zeis Planar f / 0.7 photo lens

Karl Zeis Planar f / 0.7 photo lens

Why is such a lens called super fast? We know that the amount of light passing through the lens depends on the lens aperture, on the aperture value. Discrete lenses used in cinema and photography (i.e. lenses with a fixed focal length, not zooms) usually have an aperture of 2 - this is the maximum open aperture.



View of the aperture of the aperture at different values.

View of the aperture of the aperture at different values.

This number is the **relative** aperture. The aperture number shows how many times the diameter of the inlet is less than the focal length. For example, the Zenit camera was equipped with a Helios-44 lens with a focal length of 58 mm and aperture ratio of 2. This means that the diameter of the hole through which light passes into the lens is 2 times less than the focal length, i.e. 58/2 = 29 mm. The diameter of the entrance hole from the side of the front lens is just 29 mm. (I will not discuss the difference between a geometric hole and an effective hole here.)

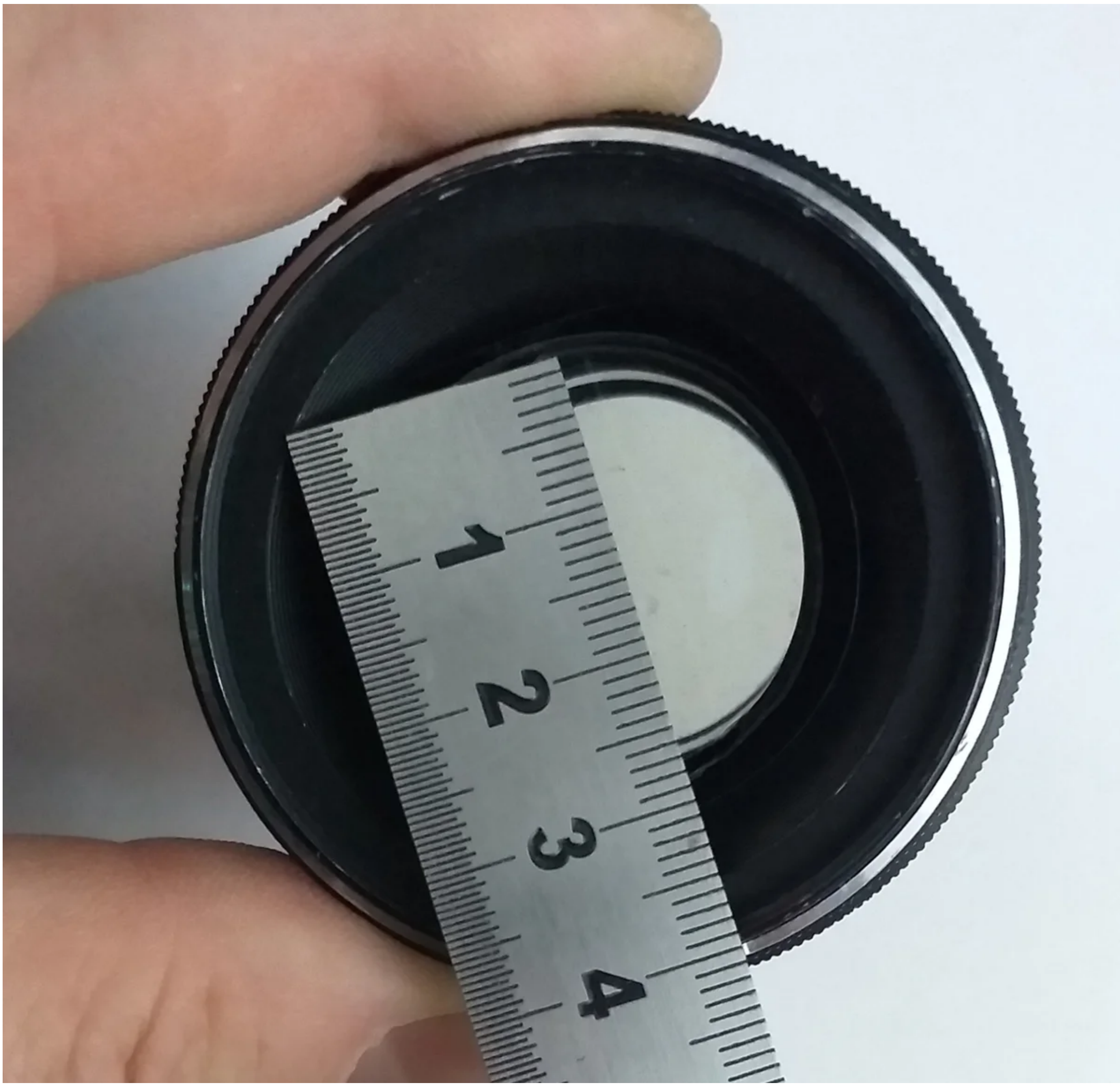
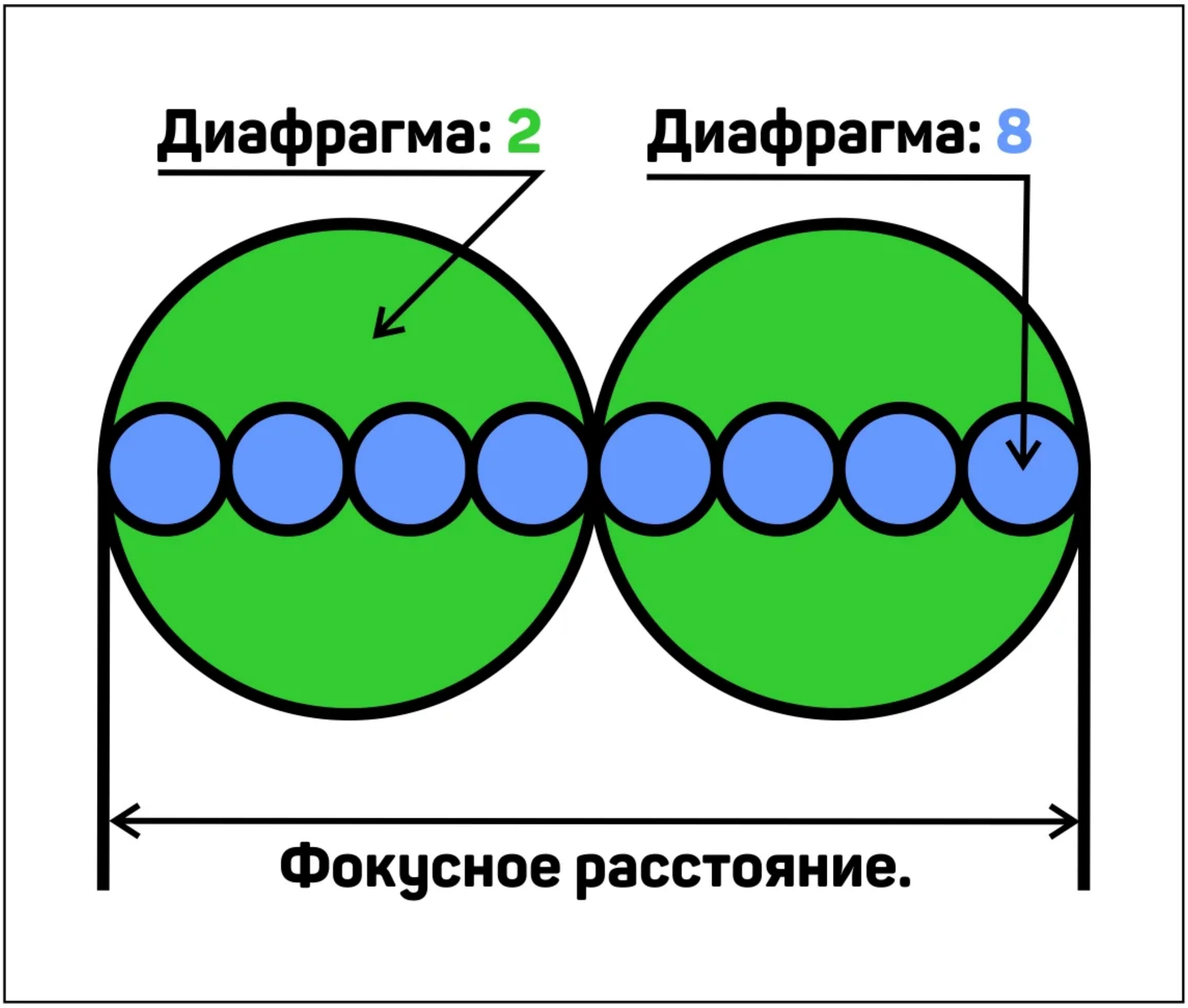


Photo lens "Helios-44". The diameter of the inlet from the front lens.

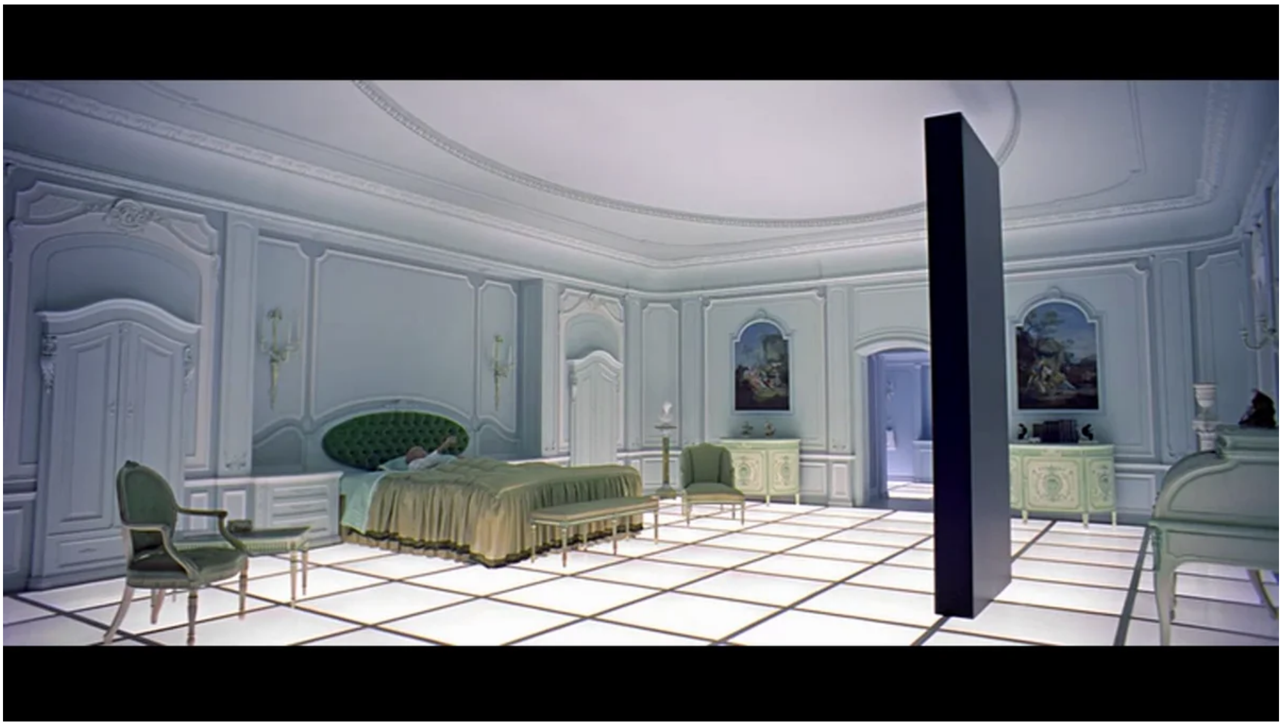
Photo lens "Helios-44". The diameter of the inlet from the front lens.

If you draw a segment equal to the focal length of the lens, then the indicated aperture diameter will fit twice on the focal length line (green circle in the figure). Aperture 8 will fit 8 times along the focal length line (blue circles).



The larger the hole diameter, the more light passes through the lens. Since the area of a circle is determined by the formula S = πR ^ 2, it is easy to understand that if the radius of the circle at aperture 2 differs from the radius of the circle at aperture 8 by 4 times, then the **area of the** hole through which the light passes differs by 16 times (four in square).

Moving from aperture 2 to aperture 0.7 ("Karl Zeis Planar f / 0.7") we get an 8x advantage in the amount of light transmitted by the lens. This lens requires 8 times less light, or, in other words, you can use lighting devices about 8 times less power. Fromfrom the previous article, you probably remember that during the filming in the pavilion, a large number of lighting equipment is used, only in one scene of the film "2001. A Space Odyssey" lighting devices with a capacity of 370 thousand watts were used.



Here, 370 thousand watts of light are involved.

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Now on sale there are lenses with aperture ratio of 1: 1 and even 1: 0.95.

Lens with aperture of 1: 0.95.

Lens with aperture of 1: 0.95.

But lenses with aperture of 1: 0.7 are not on sale yet. Those lenses made for NASA were unique. With their help, it was possible to shoot in the pavilion at light levels 8 times lower than what was required for conventional lenses.

Stanley Kubrick used these optics in the movie Barry Lyndon (1975), in scenes with candles, where there were no additional light sources. This lens has a very shallow depth of field, which is clearly visible in medium and close-ups - objects in the foreground and in the depth of the frame are very blurred.

Stills from the movie "Barry Lyndon", shot with super-high-aperture optics.

Stills from the movie "Barry Lyndon", shot with super-high-aperture optics.

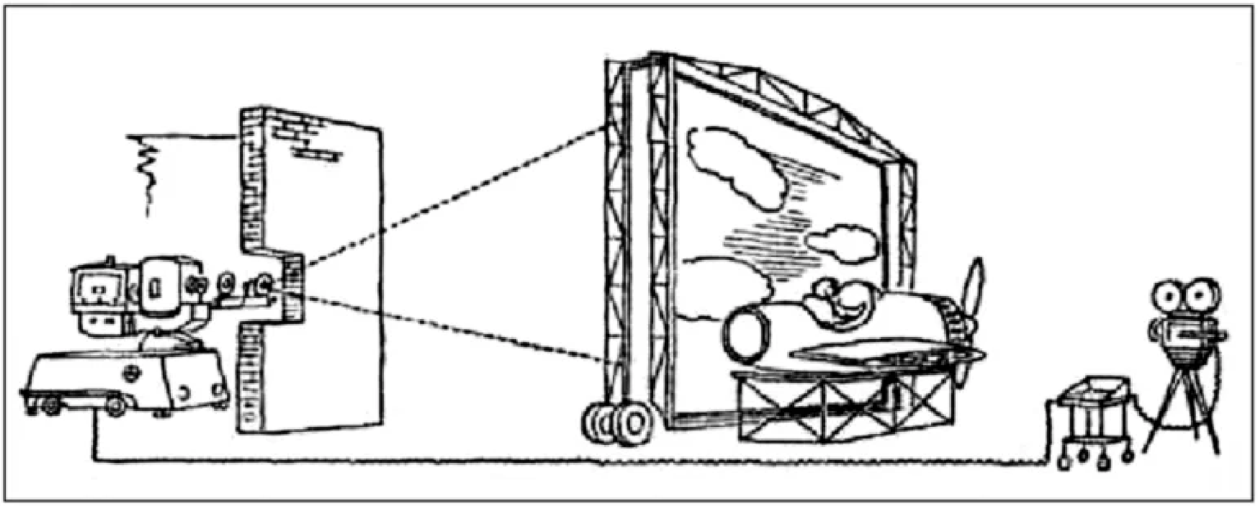
Now the question arises: why did NASA order such lenses? Is super-high-aperture optics necessary for shooting the far side of the Moon? It makes sense to photograph the opposite side of the moon when the surface is illuminated by the sun (at new moon). Illumination on the lunar surface can be about 100,000 lux, which means that it is necessary to strongly aperture the lens, not only to a value of 8 or 11, but maybe even further, to 16 or 22 (depending on the shutter speed). In sunny weather, high-aperture

optics are not needed. And when they shoot at night, they simply increase the shutter speed, the exposure time - up to several seconds (shooting a night city, shooting a starry sky), and again there is no special need for high-aperture optics. Why can ultra-high-aperture optics be useful on the Moon, and even with a small depth of field?

I've seen reports that NASA has ordered these lenses to photograph the Terminator, the line that separates day and night on the Moon. 50 years have passed since the manufacture of these lenses, but something has not been reported so that someone can shoot the opposite side of the Moon or the border of light and shadow on the Moon.

I believe that the lens has been ordered for a different purpose - not for **photo** shooting and for **movie** shooting - for peresomki images from the movie screen. On this movie screen in the pavilion, a lunar landscape was projected, and in front of the screen was an actor in a fake spacesuit depicting an astronaut. Thus, NASA planned to create the illusion of an astronaut on the moon, despite the fact that all the filming took place in the pavilion. But with a large screen size, the image brightness turned out to be very low, and only a super-fast lens could save the situation.

For decades, cinematography has used a method of combining an actor with a pre-shot landscape called keying. As soon as we show typical examples, you will immediately remember without difficulty that in old films you often noticed shots shot according to this scheme.



General view of shooting by the keying method

General view of shooting by the keying method

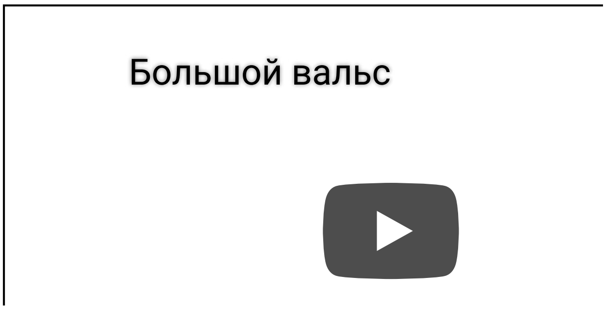
In rear projection ("rear" - from the English word "rear", behind), a movie projector that gives an image of a landscape (road or clouds) is located behind the translucent translucent screen on one side, and the camera and characters are on the other side. The shooting speed and projection speed are synchronized with a special cable to eliminate the mismatch between the shooting and projection frequencies.

The photosensitivity of negative films in the middle of the twentieth century was relatively low. Due to the low light sensitivity, it was necessary to use small-sized screens, 4-5 meters wide, in order to provide the brightness necessary for filming.

As a rule, medium and close-up shots were shot using the keying method, very often shots with a moving background outside the car window. In the 1938 film about the composer Strauss, The Big Waltz (directed by J. Duvivier), the actors sat in a motionless carriage, and the image of the moving Viennese forest was projected from behind onto a translucent screen.

Stills from the movie "The Big Waltz", shot using the keying method

Stills from the movie "The Big Waltz", shot using the keying method



DUPLICATE VIDEO: [Episode "The Birth of Music" from the movie "The Big Waltz"]

The rear projection was used by Stanley Kubrick in one of the episodes of the film "Eyes Wide Shut" (1989), when an additional plan with actor Tom Cruise was needed for editing.

Tom Cruise in Eyes Wide Shut. The frame was shot using the keying method.

Tom Cruise in Eyes Wide Shut. The frame was shot using the keying method.

In order not to arrange shooting in the city, the frame was filmed in the pavilion using the keying method. The moving landscape of the night city was projected onto the screen behind the actor.

Tom Cruise walks along the travolator in front of the movie screen (rear projection). In order not to light the screen, curtains are installed on the top of the device.

Tom Cruise walks along the travolator in front of the movie screen (rear projection). In order not to light the screen, curtains are installed on the top of the device.

And here is a shot from the movie Terminator, beloved by many viewers, 1984 - Sarah Connor runs away from an exploded fuel truck.

The use of keying in the Terminator movie.

The use of keying in the Terminator movie.

The actress was actually just running in front of the screen. A previously filmed fuel truck was projected onto this screen from behind. The height of the screen, as it is easy to understand, was slightly more than human height, and the width was about 5 meters. Since the screen is small in size, the actress, in order not to get out of focus, had to run not so much forward as diagonally along it, from left to right.

To make the explosion seem larger, a toy fuel truck, albeit a large one, was set on fire. It would be extremely dangerous to blow up a real gasoline tanker in the city.

Working moments of the scene with a fuel truck. Even a small ball of fire in relation to the layout creates the feeling of a big explosion.

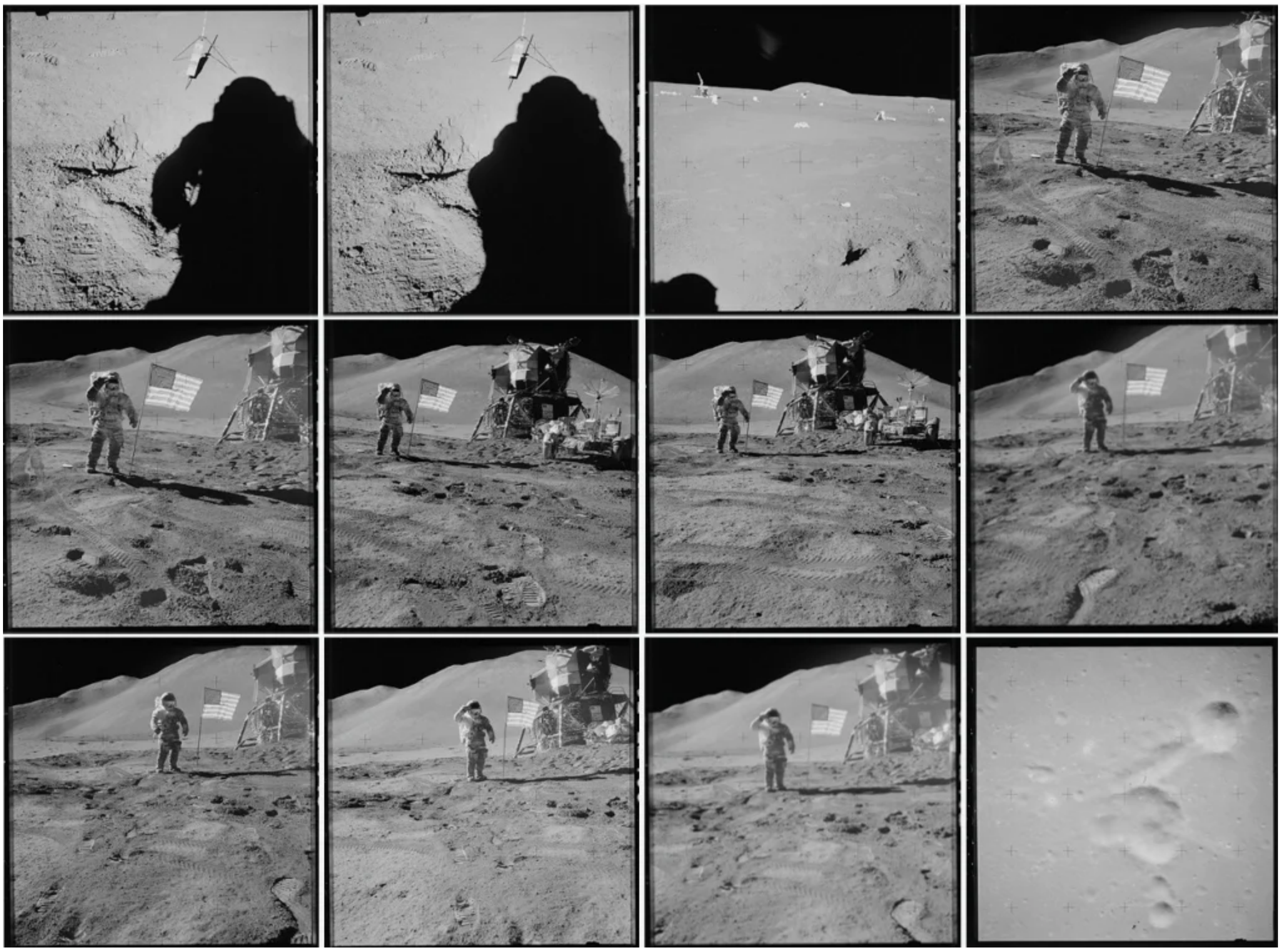
Working moments of the scene with a fuel truck. Even a small ball of fire in relation to the layout creates the feeling of a big explosion.

You are probably thinking - why are we describing in detail the method of shooting using the keying method? The fact is that it was originally assumed that this method would be used in lunar missions. The first trial "lunar" shots began to be shot already in 1967, 2 years before the "premiere" scheduled for July 1969.

But the keying method has two drawbacks that could betray a falsification. The first drawback is due to the fact that by brightly highlighting the huge lunar module and the actors "like on a sunny day", we thereby illuminate the screen located behind them, and the background becomes low-contrast, as if in an atmospheric haze (pay attention again to the frames from the film " Big Waltz ", the forest in the background is covered with haze). “Blackness” disappears on the screen, the image on the background becomes low-contrast, gray. And since there is no atmospheric haze on the Moon, there should be no drop in the contrast of illumination against the background.

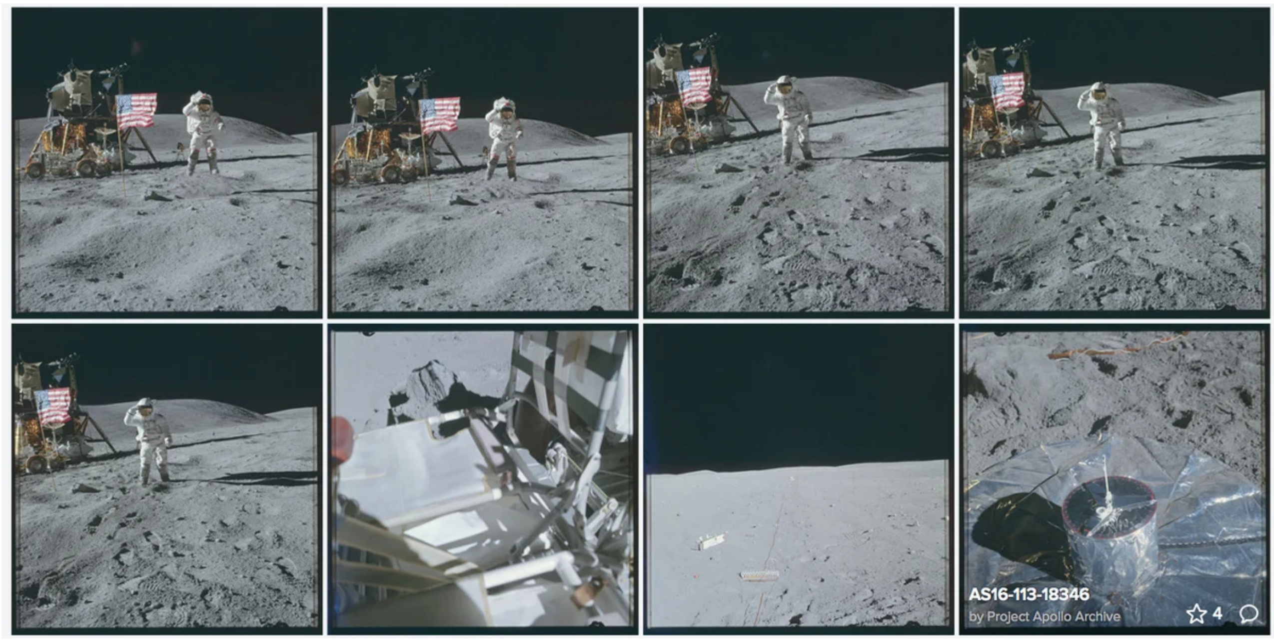
You can somehow fight this first drawback - for example, introduce bright objects into the frame against the background. In the scene from Eyes Wide Shut, most of the night street is lit up with garlands of light, shop windows and street lamps. But after all, in lunar images, almost half of the area of the frame should be occupied by the absolute "blackness" of space. For this, a legend was invented that the sun strongly illuminated the lens, therefore there are a lot of defective frames in the album, where instead of black space we see a light gray veil.

In addition, it is necessary that none of the spotlights that illuminate the actor-astronaut are directed towards the screen. In other words, a spotlight that mimics the effect of light from the sun should only illuminate the actor from behind. And since there is a movie screen directly behind the actor, the sun spotlight is placed on the side of the screen. This is where the back-side light comes from. The photographs of the various Apollo missions use the same back-side light all the time.



Black and white photographs from the album "Apollo 15"

Black and white photographs from the album "Apollo 15"



Photos from the album "Apollo 16"

Photos from the album "Apollo 16"

The second disadvantage of keying is the low brightness of the screen. Imagine that you have come to a cinema where a film is shown on a 26 meter wide screen. You can see such a 26x11 meter screen, for example, in the Oktyabr cinema on Novy Arbat in Moscow.

Hall of the cinema "October".

Hall of the cinema "October".

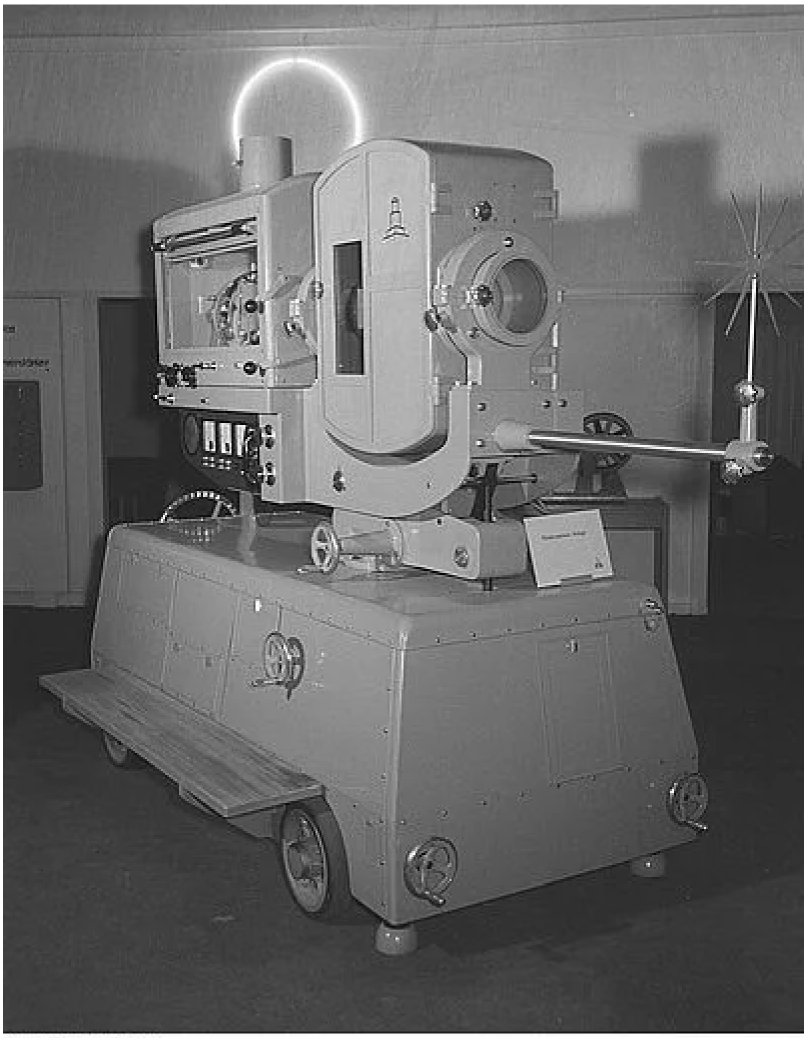
At the Aimax cinema, the screen is 24 meters wide. And now, in front of this screen, we will position the astronaut and highlight it brightly, create the effect of light, like on a sunny day. This high light level inside the hall will make the screen look very dim, even though the projectors use very powerful lamps. Most often, gas-discharge projection lamps are used, in which an electric arc shines in a bulb filled with xenon. The maximum power can reach 15-18 kW.

Aimax cinema xenon projection lamp.

Aimax cinema xenon projection lamp.

Such a lamp gives a bright white light, close in spectrum to daylight.

In rear projectors, the light source is an arc between two carbon electrodes. Powerful rear projectors operate at 78 Volts 225 Amps.



Quelle: Deutsche Fotothek

Rear projector Zeiss Ikon Dresden

Rear projector Zeiss Ikon Dresden

But even with such powerful cinema projection lamps, **during the demonstration of the film, the** illumination on the cinema screen remains at the level of 35-40 lux.

As an experiment, we tried to reshoot the image from the cinema screen with a digital camera in the video recording mode, 25 frames per second. To do this, we needed to set the sensitivity of 2000 units with an aperture of 3.5.

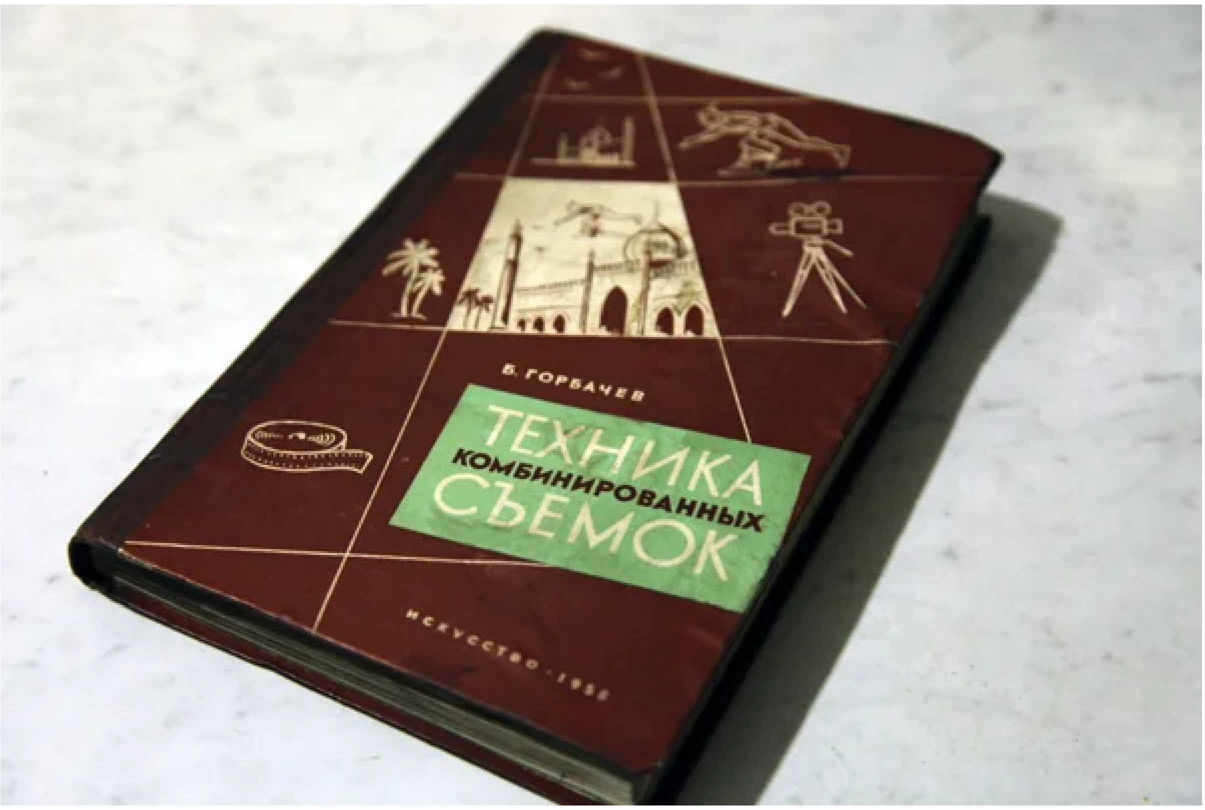
How was shooting carried out at film studios using the keying method, if in the 1960s and 1970s there were no films of such a high sensitivity, and the photosensitivity of color Kodak films was at the level of 100-125 units? According to NASA reports, 16-mm Kodak Ektachrome MS SO-368 film with a sensitivity of 160 ASA units was used for filming the films on the Moon.

Box with 16 mm Ektachrome MS SO-368 film.

Box with 16 mm Ektachrome MS SO-368 film.

It was on this film that the travels of an electric car (rover) on the so-called Moon were filmed.

In the book by B. Gorbachev "Technique of combined shooting" there is a chapter "Technical means of the method of rapid rear projection". Here is what the cameraman B. Gorbachev writes[1] about key projectors:[2]



The book of the cameraman B. Gorbachev

The book of the cameraman B. Gorbachev

"The illumination of the 3x4 m screen at 830 lux allows you to shoot on modern sensitive black and white negative films with an aperture of 1: 3.5. ... With an aperture of 1: 2.3, you can shoot on a screen that has approximately twice the area, that is, on a 4.5 x 6 m screen. This screen size allows you to shoot not only close-ups, but also medium-sized acting shots. "

And in the next paragraph, as a verdict:

"It turns out to be almost impossible to further increase the screen size."

So, the maximum screen size is limited to 4.5 x 6 meters, and this despite the fact that we use the most powerful rear projector and the most sensitive film for that period of time.

If we look at films of the 50-60s of the twentieth century, where keying was used, for example, the Western film 1954 "The river does not flow backward", then we note that the maximum width of the screen used is no more than 5-6 meters, which allows you to shoot only medium shots.

Working moment of shooting the episode on the river using the rear projection method in the film "The River Does Not Flow Backward"

Working moment of shooting the episode on the river using the rear projection method in the film "The River Does Not Flow Backward"

A finished frame from the movie “The River Does Not Flow Backward”, widescreen cinema (Cinemascope), aspect ratio 2.35: 1.

A finished frame from the movie “The River Does Not Flow Backward”, widescreen cinema (Cinemascope), aspect ratio 2.35: 1.

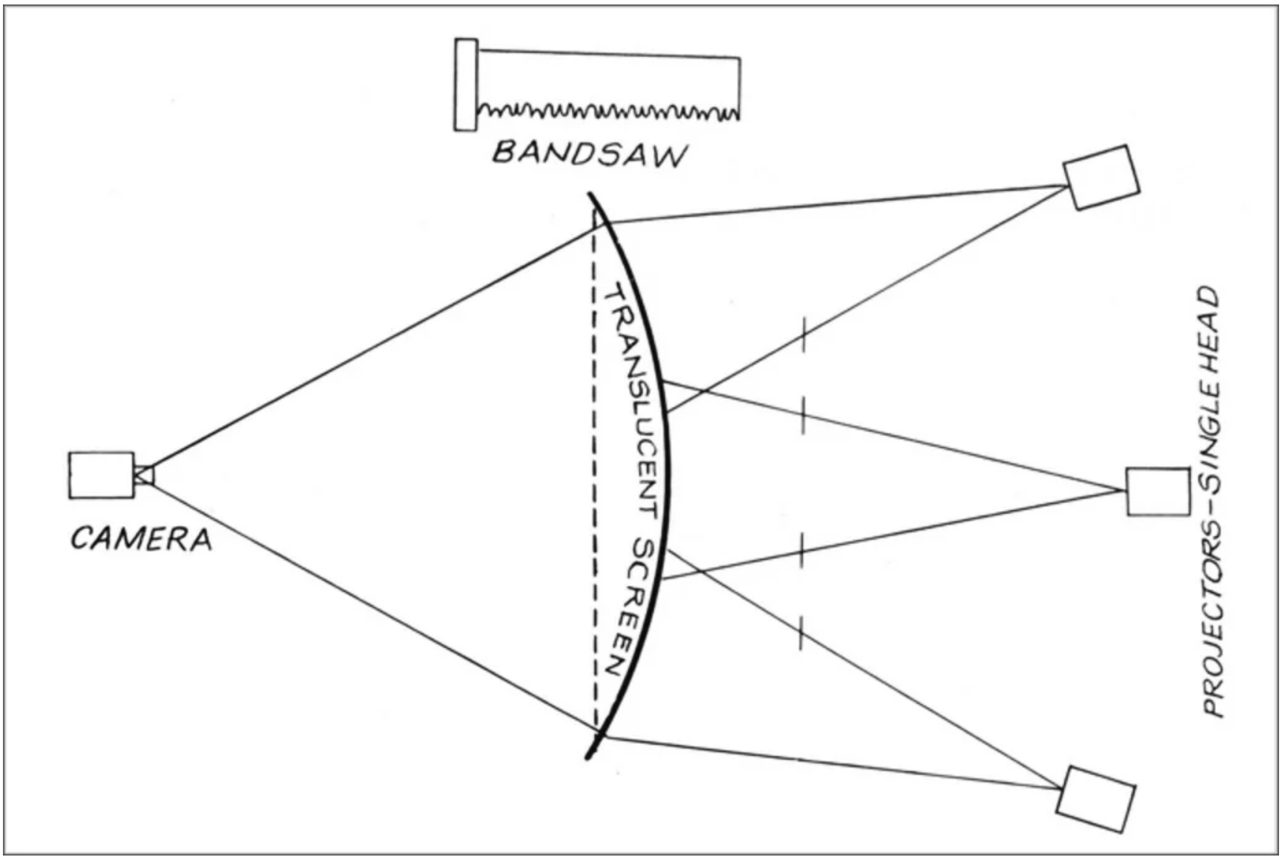
At the same time, there is still not enough depth of field: when focusing on the actors, the background is out of focus, which gives the reception of combined shots. To increase the depth of field, it is necessary to "clamp" the aperture of the lens, and this requires even more light.

For the 1962 film Mutiny on the Bounty, MGM used a 10-meter screen for rear projection.

Storm scene in the movie "Mutiny on the Bounty"

Storm scene in the movie "Mutiny on the Bounty"

Of course, a single projector could not cope with such a task. For this film, a system of three projectors working on a curved translucent screen was invented. The background of the raging waves filmed in advance was printed on three films so that at the junctions of the images, the edge of the frame resembled the teeth of a saw.



Scheme of projection onto a transmissive screen from three rear projectors

Scheme of projection onto a transmissive screen from three rear projectors

This helped to hide the vertical transition line between individual images. And, besides, in the frame, these boundaries were constantly crossed by vertical lines - cables and masts.

Also, a three-projector system was used to increase the brightness of the screen when three projectors were working on one screen. The firm "Mitchell", as B. Gorbachev reports in the book "Technique of combined shooting", made such a triple rear projector for Mosfilm, in which the middle projector gives a direct image, and the two extreme ones located on either side of it at an angle of 90 °, the images are cast onto the screen using surface mirror layer mirrors. The mirrors are fixed in frames that allow the alignment of the side projection images with the central projector image. At the same time, the brightness of the screen increased by 2.8 times.

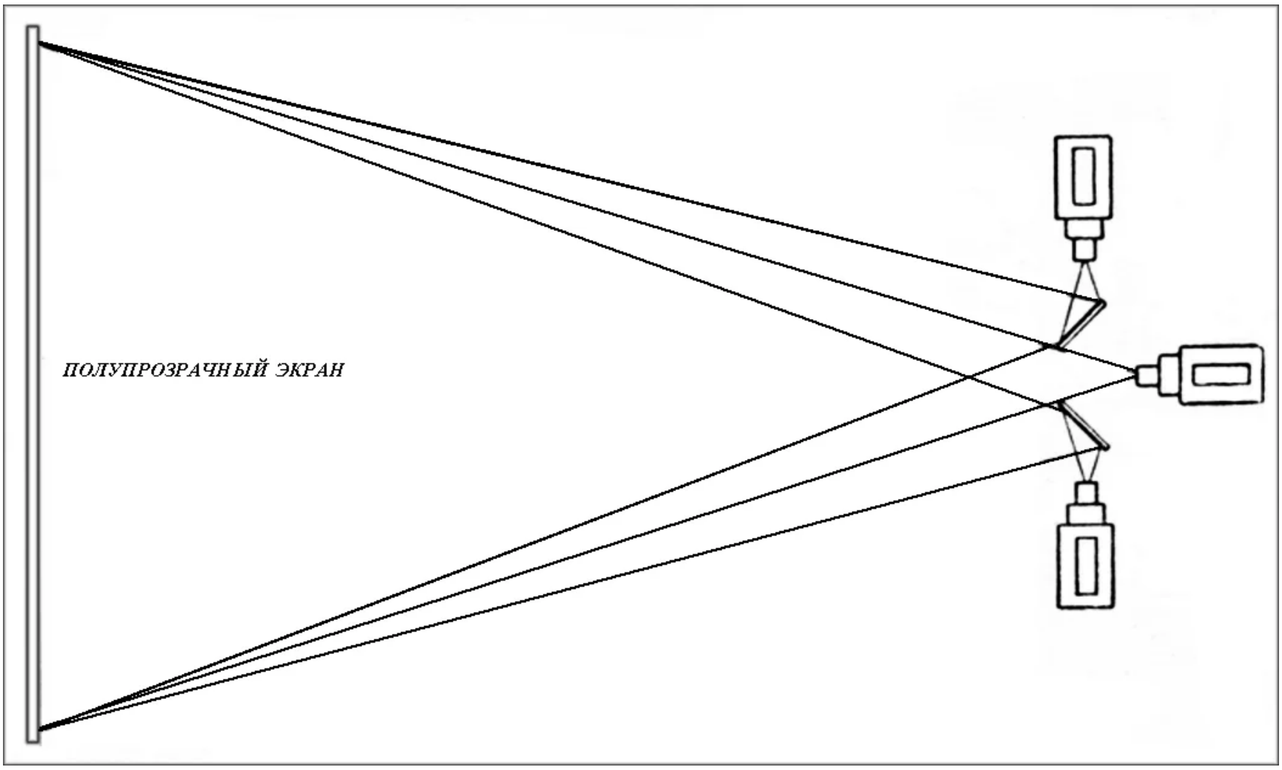
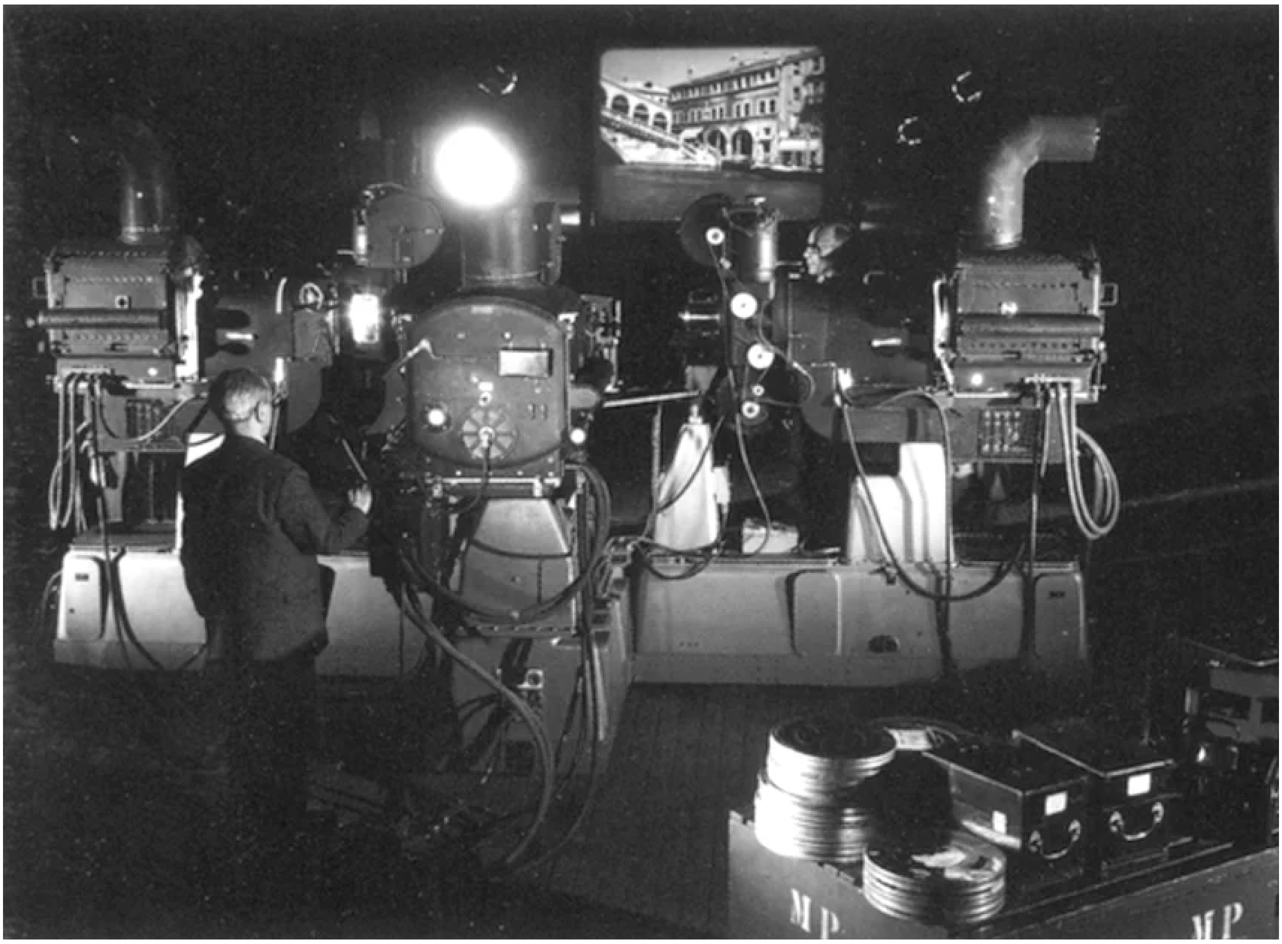


Diagram of a triple rear projection installation

Diagram of a triple rear projection installation

And this is how such a system looked in an American film studio: three identical projectors are rigidly mounted on one frame, and the light from three rear projectors is directed onto a screen located in the middle of the pavilion. In the other half of the pavilion, on the other side of the screen, there is a shooting of a game scene against the background of this image.



Built-in rear projection unit. The curved pipes at the top are the cooling system. At the back of the pavilion is the projected image.

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With keying, the drop in brightness at the edges of the screen can be very noticeable, especially with wide-angle optics. To avoid uneven illumination, projectors use long-focus optics, while the distance from the projector to the screen can reach 30 meters.

This was the cutting edge of the development of keying technology by the beginning of the 60s of the twentieth century. The maximum possible screen width for a background image is about 10 meters.

But this width is not enough to create a lunar landscape behind the astronaut actor. For such purposes, a screen with a width of about 30 meters is required.

For the projection of the "moon mountain", a movie screen about 30 meters wide was used. A still from the Apollo 15 album.

For the projection of the "moon mountain", a movie screen about 30 meters wide was used. A still from the Apollo 15 album.

And then the cinema specialists were given the task of displaying an image of sufficient brightness on a 30-meter screen to create "moon shots". The brightness should be sufficient so that you can shoot movies at 24 fps.

The first thought is to use more highly sensitive film. But Kodak could not produce more than 160 ASA **color** films. Even now, almost half a century later, the most highly sensitive film in filmmaking is Kodak 5219, with a sensitivity index of 500.

A box of modern film Kodak-5219 with a photosensitivity of 500 units.

A box of modern film Kodak-5219 with a photosensitivity of 500 units.

Since more sensitive film was not expected in the coming years, and it was impossible to increase the luminous flux of the projector further (the film melted from heat), there was only one "spare", and, moreover, an expensive option - to use **super-fast optics** when shooting .

Due to the fact that instead of the aperture 1: 2 or the real value 1: 2.3 (effective aperture) there is now 1: 0.7 (Zeiss Planar lens), we get a gain in the amount of light in (2.3 / 0, 7) ^ 2 = 10.8 times.

Now the **area of the** cinema screen can be increased by 10-11 times, or, in other words, the **width and height of the** screen can be increased by 3.3 times, approaching the coveted screen width of 30 meters.

This is the key to why NASA needed a super-fast lens that has no analogues in the world - for use in keying. From the fact that 10 lenses were manufactured already in 1967, it can

be assumed that the order for their production was received at least a year before that date, in 1966. That is, even then, in 1966, NASA knew that instead of real flights, it would film the landing on the moon in the pavilion.

However, ironically, these lenses were not needed. Stanley Kubrick, on instructions from NASA, launched the Space Odyssey project, where he developed another technology for combining an actor with an image on a movie screen - **front projection** . In the front projection, a special screen made of reflective fabric was used, a scotchlight, which, in **directional** light, created a screen brightness 100 times higher than a white canvas. The super-high-aperture lens gave a gain in light (in illumination) by only 10-11 times, and the scotchlight screen - at once by 100 times. When shooting with a super-fast lens, you would have to shoot at an open aperture, which gave a very shallow depth of field (DOF). When focusing on the astronaut, the background would be out of focus. And the reception would be noticeable.

And when the screen brightness is increased by 100 times, you can return to normal optics and even aperture to a value of 6.3, which, according to the feeling of depth of field, will give the effect of shooting on a sunny day.

This reflective material is familiar to you from road signs and stripes on workwear. In direct light (with a flash), it looks incredibly bright.

Reflective material in directional light (with flash).

Reflective material in directional light (with flash).

Women's reflective suit in diffused and directional light. The white screen appears almost black against the reflective material (pictured right) in the background.

Women's reflective suit in diffused and directional light. The white screen appears almost black against the reflective material (pictured right) in the background.

The first successful experiments with front-projection onto a 30-meter screen date back to July 1967, and the entire front projection systems were developed by S. Kubrik only by October 1967. The above photo frame from the album "Apollo 15" - the astronaut against the background of the mountain, was obtained just by the front projection method.

We wrote about the front projection scheme and reflective material in the article "The most famous lunar photograph from the Apollo 15 mission was taken in the pavilion using the front projection method .

*

[1] Help:

B.K. Gorbachev. Director of photography, operator of combined shooting. The author of the development of original methods of combined filming ("the method of a wandering mask" in the film "The Light Path" (1940). The method of "wandering mask" is also used in the film: "Children of Captain Grant" (1936), "The Magic Seed" (1942), " Cherevichki " (1945)," Cinderella "(1947)," Sadko "," Admiral Ushakov "," Ships storm the bastions "(all in 1953)," Merry Stars "(1954)," Height "(1957)," Russian souvenir "(1960), in which Gorbachev participated as a combined filming operator.

[2] B. Gorbachev. Combined filming technique, GIZ, Art, Moscow, 1961, p. 190

*

Cameraman L. Konovalov was with you. Until next time!

Front projection scheme

Front projection scheme